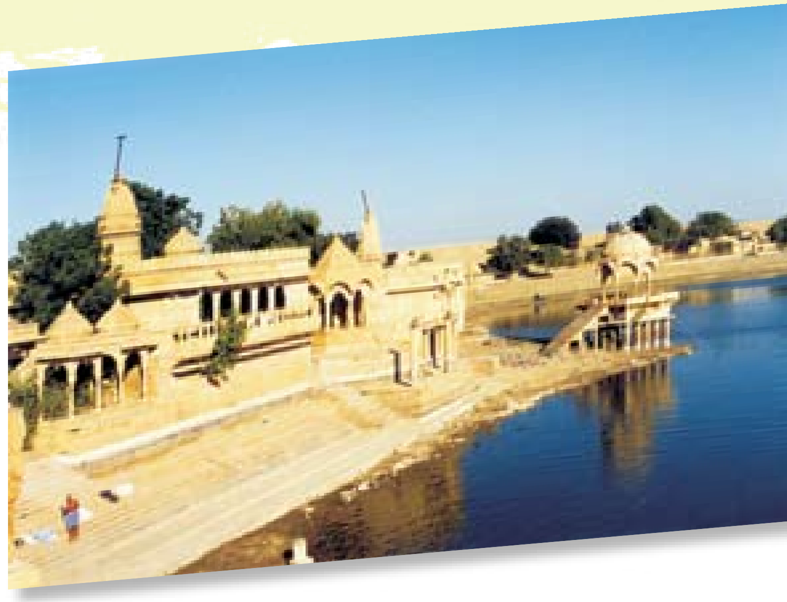
High Performance Commercial Buildings in India

Initial Project Findings

Supported by:

Bureau of Energy Efficiency
Government of India
and
United States Department of State

Background



Buildings account for at least 40% of energy use in most countries. The construction sector in India is witnessing a fast growth due to several factors. Some of the key growth drivers are increased demand for housing, strong demographic impetus, expansion of organized retail, increased demand for commercial office spaces by multinationals and IT (information technology) hubs, and coming up of SEZs (special economic zones). The gross built-up area added to commercial and residential spaces was about 40.8 million square metres in 2004/05, which is about 1% of annual average constructed floor area around the world, and the trend shows a sustained growth of 10% over the coming years. With a near consistent 8% rise in annual energy consumption in the residential and commercial sectors, energy consumption in buildings has seen an increase from a low of 14% in the 1970s to nearly 33% in 2004/05. This is directly related to higher greenhouse gas emissions, which can be countered by constructing high performance energy-efficient buildings.

To fulfil this objective, TERI (The Energy and Resources Institute), in association with White Box Technologies, USA, has undertaken a project 'High performance commercial buildings in India' so as to make commercial buildings in India energy efficient.

About the ECBC

The Bureau of Energy Efficiency, Government of India, launched the ECBC (Energy Conservation Building Code) in 2007 for commercial buildings with peak demand in excess of 500 kW or connected load in excess of 600 kVA.

Analysis done during the development of the ECBC shows energy savings in the range of 27%-40% in an ECBC-compliant building over a typical commercial building with annual energy consumption of 200 kWh/m^2.

The ECBC sets minimum energy performance standards for the design and construction of large commercial buildings. It encourages energy-efficient building systems, such as building envelope; lighting; HVAC (heating, ventilation and air conditioning); water heating; and electric power distribution, within the building facilities while enhancing thermal and visual comfort, and productivity of the occupants.

About the project

The project on 'High performance commercial buildings in India', which is being undertaken under the aegis of the Asia-Pacific Partnership on Clean Development and Climate, aims at establishing relevance and impacts of low-energy passive strategies and ECBC-recommended measures on improving energy performance of commercial buildings in five climatic zones of India.

High performance buildings in India would be defined as buildings that have integrated low-energy/solar passive architectural design strategies and energy efficiency measures, as recommended by the ECBC 2007.

However, energy-efficient buildings did exist in pre-ECBC era also, which managed to achieve satisfactory energy savings through the adoption of low-energy/solar passive design strategies, such as proper orientation, shading, natural ventilation, daylighting, and so on, to reduce energy consumption and meet required thermal/visual comfort norms as per Indian codes and standards.

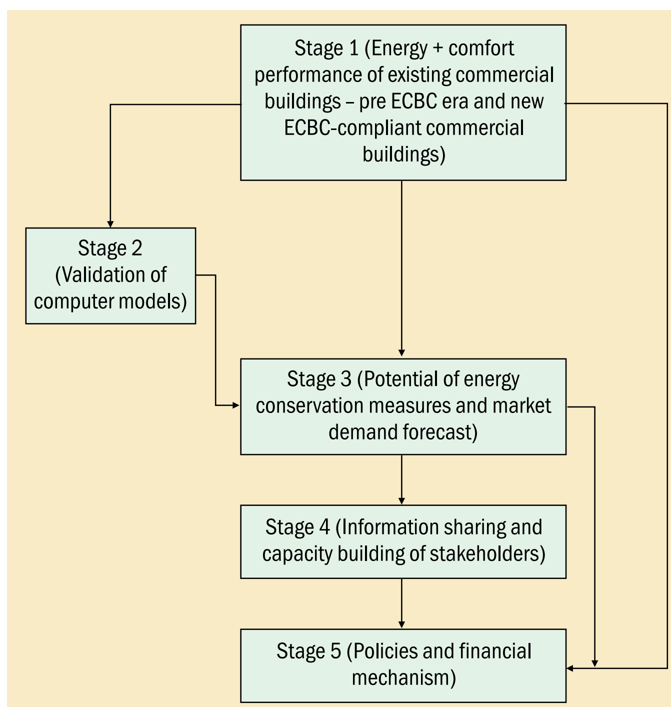


Figure 1 Various stages of the project

Partners

The project is supported and funded by the US Department of State and the Bureau of Energy Efficiency, Government of India. It is being implemented by TERI, India, and White Box Technologies, USA.

Stages of the Project

The various stages of the project are demonstrated graphically in Figure 1. The project has various steps and stages and is proposed to be carried out over a period of three years, with two more years to go.

Findings of the study

Ten sample buildings from five climate zones (hot and dry; composite; warm and humid; moderate; and cold) were selected for the study. Five of these buildings (one building per climate zone) were conventional buildings (features and energy performance summarized subsequently) and the remaining five (one from each climate zone) were low-energy buildings that had demonstrated the use of passive features/ low-energy strategies (summarized subsequently). It must be noted that the selected low-energy buildings have the comfort levels same as those in conventional buildings, the only difference being the former uses much lesser energy. Though these buildings are partly/fully air-conditioned, they have deployed climate-responsive techniques such as proper orientation, shading devices, appropriate wall to window ratio, and integrated use of daylight to reduce energy consumption.

The selection of the buildings was done in consultation with the Bureau of Energy Efficiency, building owners, architects, and other stakeholders (Figure 2). TERI's past experience and earlier studies/energy audit reports were also utilized for the study.

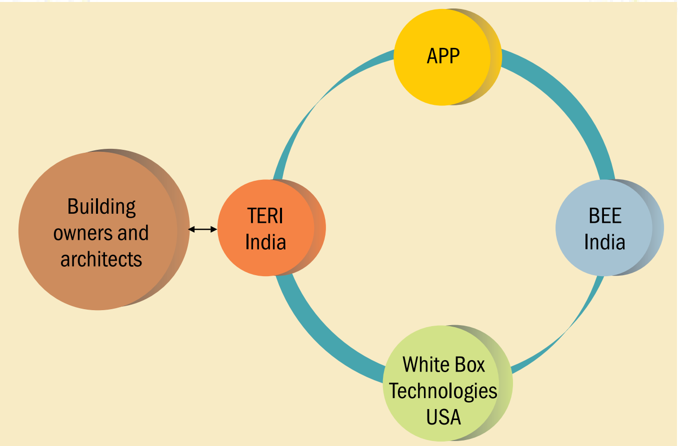


Figure 2 Various stakeholders of the project

Features of the buildings studied

The next step was the establishment of the Energy Performance Index, energy consumption trends, and performance parameters of the five conventional buildings. The energy and comfort audit of the five existing low-energy buildings was also done to establish the Energy Performance Index and the comfort parameters. The findings relevant to the study are summarized in Table 1.

The next step was to validate energy performance of the low-energy/solar passive buildings by using computer simulation techniques (Figure 3). The following steps were followed for the validation exercise.

- Detailed energy and visual/thermal comfort audit in these buildings was carried out.
- The energy performance of the buildings was estimated using established computer simulation tool (Visual Doe 4.0).
- The model was calibrated and validated using the audited data and vice versa.
- The validated model was used to carry out parametric analysis and suggest improvement in the Energy Performance Index through various interventions, including the application of the ECBC 2007.

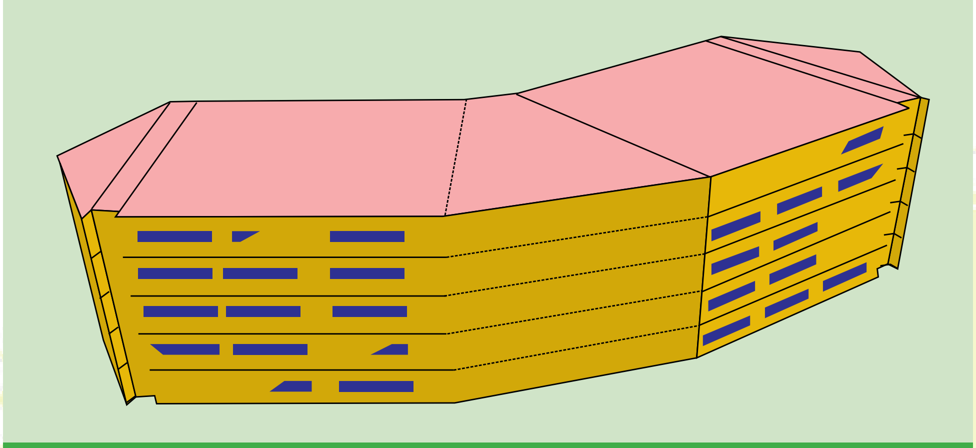


Figure 3 Computer simulation model for Wipro Technologies, Kolkata

Table 1 Performance parameters of conventional and low-energy buildings

Parameter	*Conventional buildings*	*Low-energy buildings*
Design features	Long facades east–west.	Long facades north–south.
	No shading.	Shading of east–west façade.
	Single glazed windows.	Mix of single and double glazed windows.
Lighting system	No daylight integration.	Daylight and artificial lighting integration.
	No lighting controls.	Occupancy sensors and dimming controls.
	Lighting power density is in the range 15–20 W/m^2.	Lighting power density is less than 15–20 W/m^2.
	Visual comfort maintained as per the National Building Code 2005.	Visual comfort was maintained as per the National Building Code 2005.
Air conditioning system	No natural ventilation or passive cooling techniques.	Circulation areas are naturally ventilated.
	Chillers used are reciprocating chillers.	Chillers used are screw and centrifugal chillers.
	Percentage of air-conditioned area to built-up area is above 60%.	Percentage of air-conditioned area to built-up area lies in the range 50%–65%.
	Chiller coefficient of performance was on the lower side.	Chiller coefficient of performance is on the higher side.
	Sqmt/TR (tonne of refrigeration) lies in the range 9–15.	Sqmt/TR lies in the range 32–42.
	Thermal comfort was maintained as per the National Building Code 2005.	Thermal comfort maintained as per the National Building Code 2005.
Energy performance	Lighting Performance Index lies in the range 37–60 $kWh/m^2/year$.	Lighting Performance Index lies in the range 21–28 $kWh/m^2/year$.
	Air Conditioning Performance Index for different climatic zones are: ■ **Warm and humid** – 263 kWh/m^2 per year (10 hours operational) ■ **Moderate** – 259 kWh/m^2 per year (10 hours operational) ■ **Composite** – 183 kWh/m^2 per year (10 hours operational) ■ **Cold** – 251 kWh/m^2 per year (24 hours operational)	Air Conditioning Performance Index for different climatic zones are: ■ **Warm and humid** – 195 kWh/m^2 per year (24 hours operational) ■ **Moderate** – 105 kWh/m^2 per year (10 hours operational) ■ **Composite** – 144 kWh/m^2 per year (10 hours operational) ■ **Cold** – 41 kWh/m^2 per year (10 hours operational)

Case study of solar passive/ low-energy building in warm and humid climate zone

This particular case study demonstrates the relevance and impacts of low-energy strategies and ECBC measures on the energy performance of the building of Wipro Technologies Ltd, located in the warm and humid climate zone of India (Figure 4). Wipro Ltd, located at Sector V Salt Lake in Kolkata, is a software development and IT-enabled service provider, delivering technology-driven business solutions that meet the strategic objectives of the client. With a built-up area of 39 900 m^2, the IT service house comprises Tower 1, Tower 2, Tower 3, a learning centre, a cafeteria, and a guest house. The facility is operational 24 × 7. The project architect is M/S Ghosh Bose and Associates, Kolkata.

The energy and comfort audit was done by the TERI team during the month of June 2008. The technical team from Wipro also participated in the audit and shared all relevant data for the study. The salient features and performance parameters of the building are given in Table 2.

To study the impact of energy saving measures on the existing building, a computer simulation model was developed with the help of architectural drawings, installed lighting load, HVAC system configuration, equipment load, and building envelope parameters collected during the audit. This model was calibrated and validated to match with audited data. The parameters that were validated are cooling demand, and electricity and energy consumption.

Parametric studies

Parametric studies were done using the validated and calibrated model on two sets of cases: conventional case

Figure 4 Wipro Technologies, Kolkata, warm and humid climate zone

Table 2 Performance parameters of Wipro building

Parameter	
Design features	Long facades are inclined at 45° to north.
	WWR (window to wall ratio) is 11% (it may be noted that ECBC [Energy Conservation Building Code] limit of WWR is 60%. So, this building has much lower WWR than the ECBC).
	Uninsulated walls and roof; single glass with a shading coefficient of 0.52.
Lighting system	LPD (lighting power density) is 6.9 W/m^2 (it may be noted that ECBC LPD limit is 10.8 W/m^2).
	Visual comfort was maintained as per the National Building Code Standard.
Air conditioning system	Circulation areas are naturally ventilated.
	Chillers used are water-cooled centrifugal.
	Percentage of air-conditioned area to total area is 65%.
	Chiller coefficient of performance is 5.1.
	Air handling units are equipped with variable frequency drives.
	Sqmt/TR (tonne of refrigeration) is 32.
	Thermal comfort maintained as per the National Building Code Standard.
Energy performance (24 hour operational)	Lighting Performance Index is 23 kWh/m^2/year.
	Air Conditioning Performance Index is 195 kWh/m^2/year.
	Overall Energy Performance Index is 218 kWh/m^2/year*.

*Includes lighting and HVAC consumption only

and existing case. Table 3 explains the important parameters in the various cases.

Once the calibration was done, a conventional case was generated from the calibrated model. The reason for generating the conventional case was to study the impact of energy efficient measures that have already been taken in the existing building (it may be noted that the existing building is well oriented and has low light power density, and for the purpose of this study, it is important to analyse the impact of each low-energy/energy efficiency strategy on the energy performance of the building). Following are the differences between the conventional case and the calibrated/existing case of the model.

- Orientation in the conventional case changed to longer façade facing east-west.
- Lighting power density in the conventional case is 20 W/m^2.

Table 3 Various parameters in different scenarios

Parameter	*Existing case*	*Conventional case*	*Best case for conventional and Wipro buildings*
Building design	Longer facades of the building are 45° inclined to north.	Building orientation was changed to longer facades facing east–west.	Longer facades of the building are facing north–south.
	No roof and wall shading.	No roof and wall shading.	Wall and roof shading.
	No insulation on wall and roof.	No insulation on wall and roof.	Wall and roof changed to ECBC (Energy Conservation Building Code)-recommended wall and roof.
	U-value for wall: 1.92 W/m²/K.	U-value for wall: 1.92 W/m²/K.	U-value for wall: 0.44 W/m²/K.
	U-value for roof: 2.74 W/m²/K.	U-value for roof: 2.74 W/m²/K.	U-value for roof: 0.261 W/m²/K.
Building envelope	Single glazed windows (U-value of glass: 5.7 W/m²/K and shading coefficient: 0.52).	Single glazed windows (U-value of glass: 5.7 W/m²/K and shading coefficient: 0.52).	Glazing was changed to ECBC-recommended glazing (U-value of glass: 3.3 W/m²/K and shading coefficient: 0.287).
Building lighting power density	Lighting power density is 6.9 W/m².	Lighting power density changed to 20 W/m².	Lighting power density changed to ECBC-recommended lighting power density, that is, 10.8 W/m², for conventional case and was not changed for existing case, as for the existing case lighting power density is 6.9 W/m², which is efficient than ECBC-recommended lighting power density.
Building chiller	Centrifugal water-cooled chiller having a coefficient of performance 4.93.	Centrifugal water-cooled chiller having a coefficient of performance 4.93.	ECBC centrifugal water-cooled chiller of coefficient of performance 6.3 was selected for a building having a cooling demand of 400 TR (tonne of refrigeration).
Energy-efficient controls	VFD (variable frequency drive) on AHUs (air handling units).	VFD on AHUs.	VFD on AHUs.

The conventional case described above was selected to run different energy saving options and, finally, quantify the energy saving potential that can be realized by incorporating the low-energy strategies, ECBC envelope, ECBC lighting power density, and ECBC chiller. The different energy saving options incorporated in the conventional case HVAC model are explained in detail in the subsequent sections.

Impact of low-energy strategies

Low-energy strategies include true north-south orientation, wall shading, and roof shading.

The conventional case HVAC model was run by incorporating the above-mentioned low-energy strategies, and the following results were obtained (Figure 5).

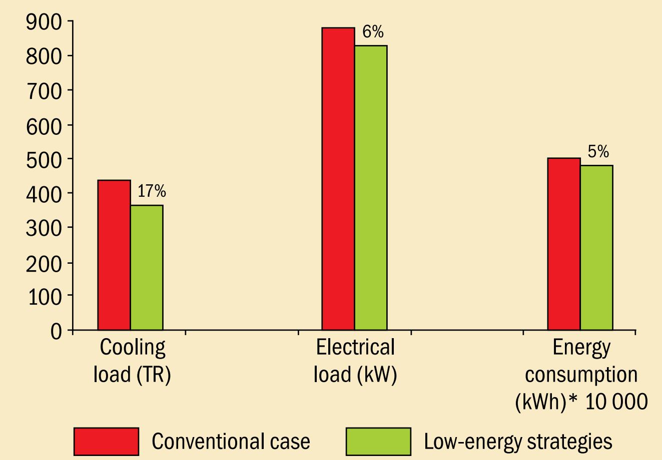


Figure 5 Impact of low-energy strategies

- Saving potential in cooling load (TR [tonne of refrigeration]) is 17%.
- Saving potential in electrical load (kW) is 6%.
- Saving potential in energy consumption (kWh) is 5%.

Impact of the ECBC envelope

The ECBC envelope comprising wall, roof, and glass complied with the recommendations made by the ECBC for warm and humid climate.

The conventional case HVAC model was run by incorporating the ECBC envelope, and the following results were obtained (Figure 6).

- Saving potential in cooling load (TR) is 13%.
- Saving potential in electrical load (kW) is 5%.
- Saving potential in energy consumption (kWh) is 5%.

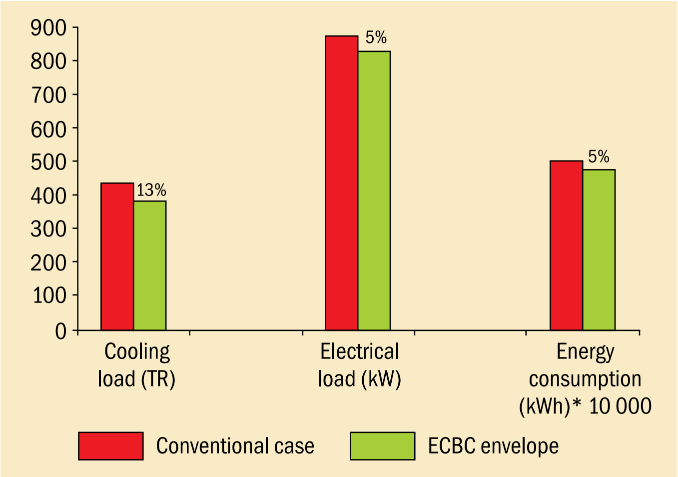


Figure 6 Impact of the ECBC envelope

Impact of the ECBC lighting power density

The ECBC lighting power density is 10.8 W/m^2 for an office building in warm and humid climate.

The conventional case HVAC model was run by incorporating the ECBC lighting power density, and following results were obtained (Figure 7).

- Saving potential in cooling load (TR) is 9%.
- Saving potential in electrical load (kW) is 12%.
- Saving potential in energy consumption (kWh) is 13%.

Impact of the ECBC chiller

The ECBC chiller for a building having a cooling demand of 400 TR is a water-cooled centrifugal chiller with a coefficient of performance 6.3.

The conventional case HVAC model was run by incorporating the ECBC chiller, and the following results were obtained (Figure 8).

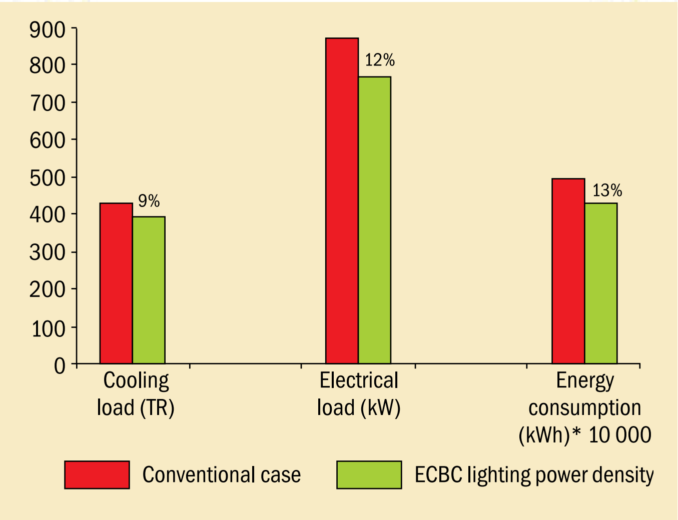


Figure 7 Impact of the ECBC lighting power density

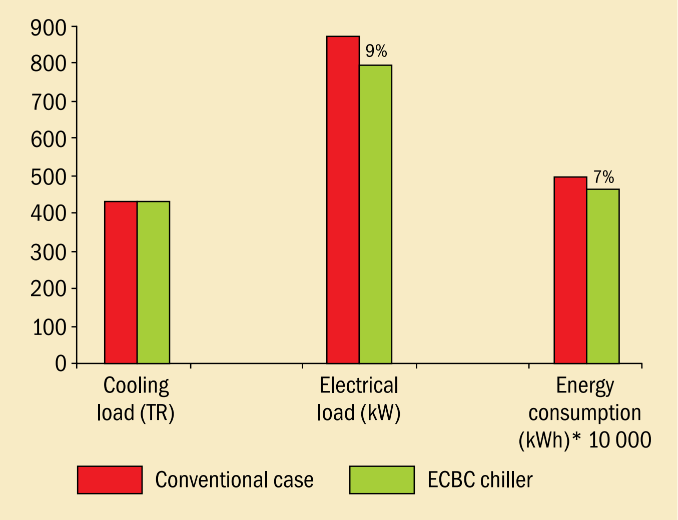


Figure 8 Impact of the ECBC chiller

- Saving potential in electrical load (kW) is 9%.
- Saving potential in energy consumption (kWh) is 7%.

Overall impact of low-energy strategies, ECBC envelope, ECBC lighting power density, and ECBC chiller

Figure 9 shows the overall impact of energy efficiency measures on conventional case and (Wipro) existing/calibrated case. The overall saving potential that can be realized by incorporating all the above energy saving measures in conventional best case in warm and humid climate is as follows.

- Overall saving potential in cooling load (TR) is 30%.
- Overall saving potential in electrical load (kW) is 25%.
- Overall saving potential in energy consumption (kWh) is 24%.

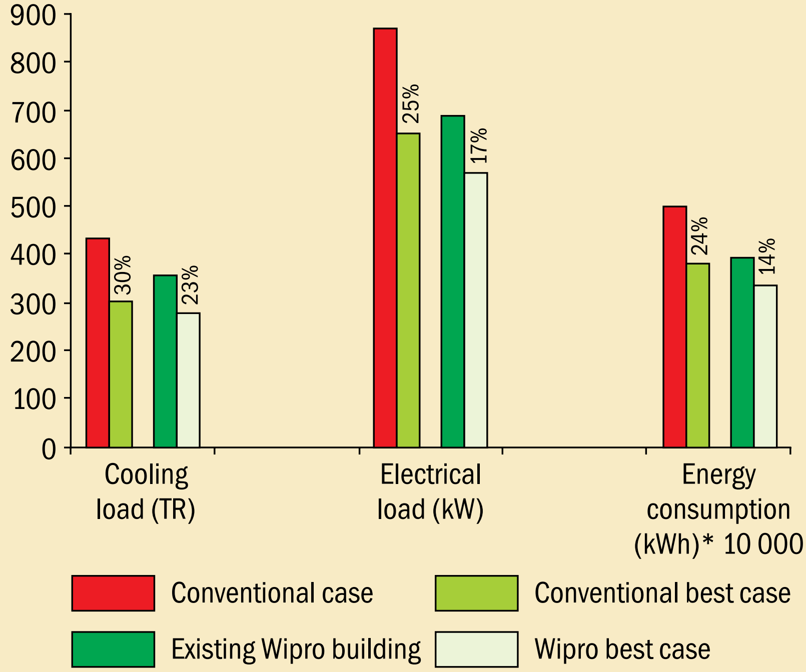


Figure 9 Overall impact of low-energy strategies, ECBC envelope, ECBC lighting power density, and ECBC chiller on conventional case and existing Wipro building

Although the existing Wipro building is equipped with low-energy/solar passive strategies, the saving potential can be realized by incorporating the above energy saving measures. The overall energy saving potential that can be realized in the existing Wipro building (in Wipro best case in Figure 9) is summarized as follows.

- Overall saving potential in cooling load (TR) is 23%.
- Overall saving potential in electrical load (kW) is 17%.
- Overall saving potential in energy consumption (kWh) is 14%.

Conclusion

- From the foregoing discussion, it is clear that climate-responsive design features should be in tandem with ECBC recommendations so as to realize maximum energy savings. It would be important to note that the spaces that needed air conditioning have been carefully chosen in the study, and circulation areas were left as naturally ventilated spaces.
- Although low-energy buildings do not follow the ECBC recommendations, the Energy Performance Index (kWh/m^2) for these buildings is very low as compared to the conventional buildings. The features that contribute to low energy consumption are as follows.
  - North-south orientation
  - Shading of the west façade
  - Shading of roof
  - Large window openings on north-south façade
  - Least exposure and windows on east-west façade
  - Natural ventilation for circulation areas

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